British Rail

TECHNICAL TRAINING NOTE **APT** 1

INTRODUCTION TO THE ADVANCED PASSENGER TRAIN

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2. Research & Development Programme
3. Development of APT-P
4. Design Speed
5. Vehicle Structures

RAILWAY ENGINEERING SCHOOL,
BRITISH RAILWAYS, DERBY.

TYPICAL APT SPEED IMPROVEMENT ON CURVES

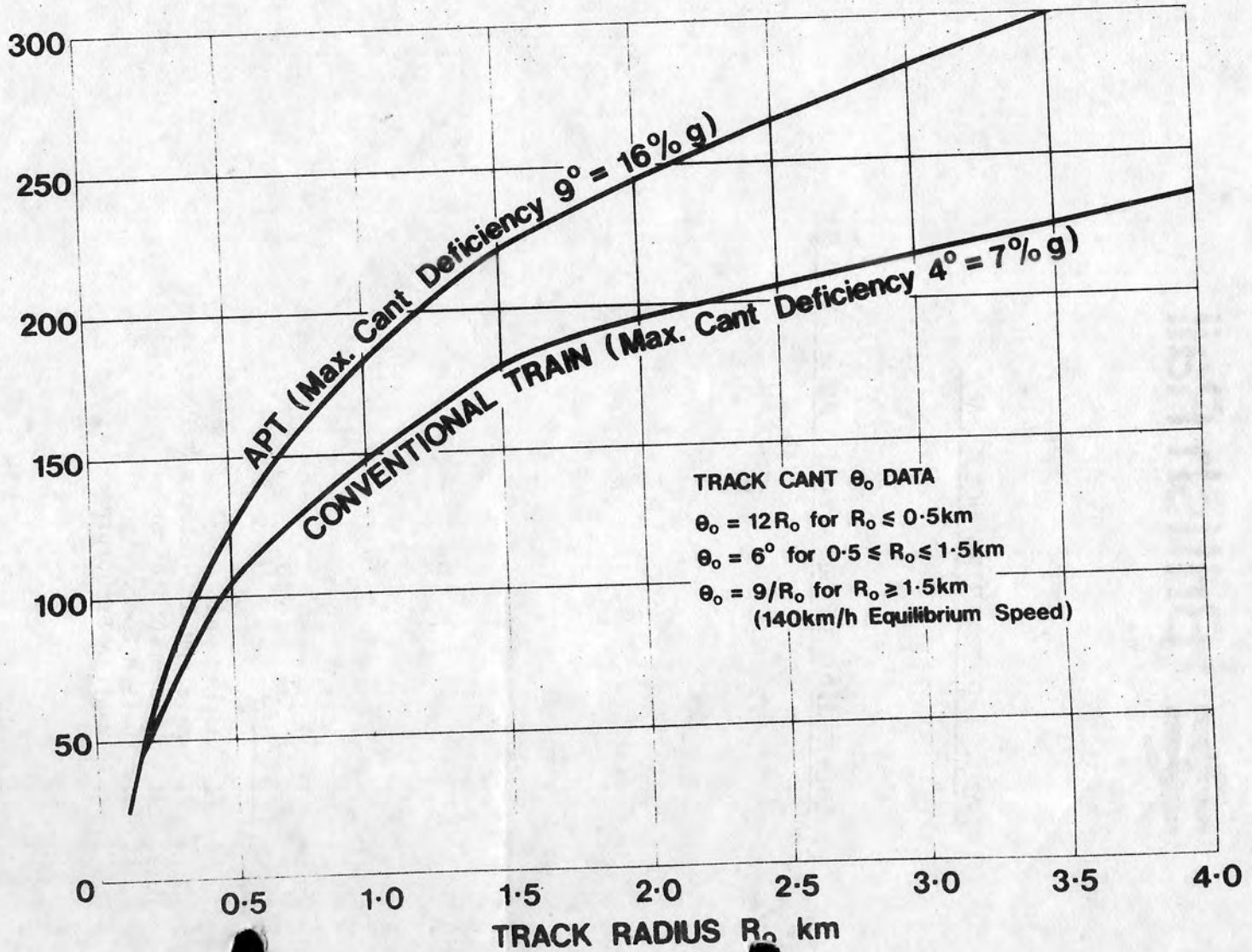


FIGURE 1

APT	1		1

BRITISH RAIL

TECHNICAL TRAINING NOTE APT/1

INTRODUCTION TO THE ADVANCED PASSENGER TRAIN

1. BACKGROUND

The concept of an 'Advanced' passenger train grew from research during the period 1962-1967 into the dynamics of four-wheeled vehicles. Such work produced a series of high speed freight vehicles and the first of these (HSFV 1) reached a stable 140 mile/h on a roller rig at the Derby Laboratories.

Project feasibility study for APT began in 1968 to see how present journey times could be reduced, the success of our West Coast main line electrification and the Japanese Tokaido line conclusively supporting this aim. At an early stage it became evident that the economics did not favour new (and straighter) railway lines which are required if conventional trains are to achieve higher average speeds. On our major trunk routes approximately half of the mileage is made up of curves and half of those curves are between 1 760 ft and 6 600 ft. With a maximum track cant of 6" a 100 mile/h train can negotiate a minimum curve of 3 770 ft radius but if the speed is raised to 125 mile/h the limiting radius is 5 900 ft. Vehicle 'cant deficiency' is conventionally limited to $4\frac{1}{2}^{o}$, this being judged to be the boundary for passenger comfort, but such a limit is in fact considerably below safe levels of operation in curves. (This limit has been investigated by actually derailing a coach under controlled conditions).

To overcome the 'comfort boundary' problem, APT tilts the body of each vehicle up to 9^{o} such that the passenger does not feel any effects of steady curving. The APT can consequently negotiate curves 20-40% faster than a conventional train (See Fig. 1).

2. RESEARCH AND DEVELOPMENT PROGRAMME

2.1 General

The original starting point for APT was a basic theory of guidance and stability which recognised that guidance was available from a pair of coned wheels and that the guidance was maximised by increasing the cone angle. Unfortunately increased cone angle decreases the dynamic stability of the vehicle and consequently there is conflict between the requirements of guidance and stability. This is evidenced by past railway 'practice' of turning tyres at a given mileage so as to restore the ride up a vehicle to an acceptable level. The solution required lengthy research and development culminating in the design of bogies which are both stable and curve without creating high forces. There was considerable 'spin off' from this and other APT work.

To enable accurate design uniformation to be amassed a considerable amount of work was conducted by the Research & Development Division to determine the characteristics of the track that we have to run on-its shape, its stiffness its statistical roughness and the frequency of occurrence of discrete irregularities such as crossings. Using this information the design cases for the vehicle suspensions were based upon the need to limit track damage and also provide a high standard of ride comfort.

The articulated configuration decided upon enables the design axle-load to be achieved in addition to supporting the requirements for stability, low train mass, low energy consumption and reduced bogie costs. Noise levels were reduced (see Fig 2) simply by having less wheels!

Articulation and low train mass dictated a need for very light vehicles; trailer cars are constructed in aluminium using a unique method of welding together vehicle-length extrusions. Weight is 40% less than conventional steel construction and costs are comparable. Power cars are fabricated in steel to a monocoque design. Trailer car axle loads vary from about 11 tonne tare to between 13-15 tonne depending on the type of vehicle. Power car axle load is about 17 tonne.

Further information on vehicle structures is given on pages 10 and 11.

PREDICTED TRAIN NOISE LEVELS
(25 m From Track)

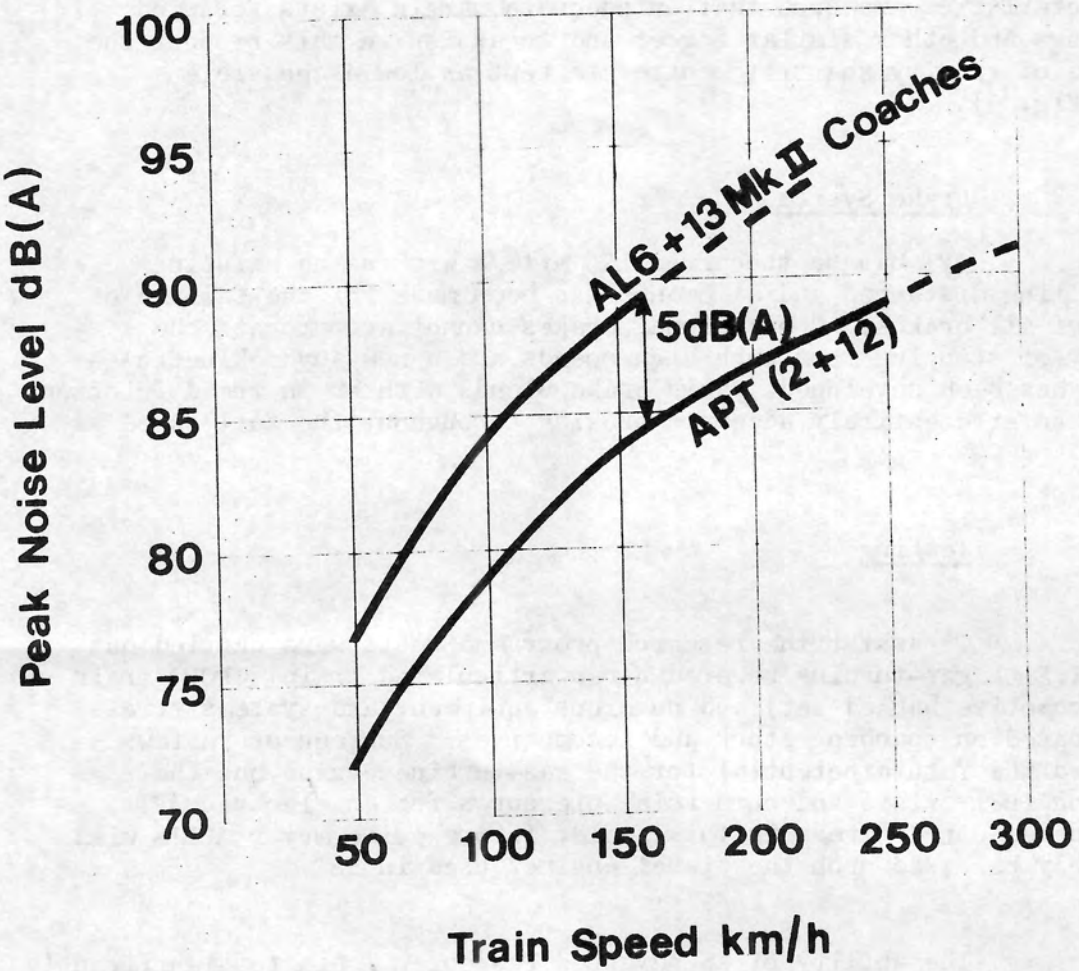


FIGURE 2

2.2 Tilt System

Tilt of the APT had a strong influence upon the design of the vehicle, the most evident effect being on the body profile. Not so evident is the choice of control system characteristics to give a smooth tilting action through transition curves. The curving characteristics are such that an adequate margin exists for wind loadings and other similar forces and to assist in this respect the centre of gravity and tilt centre are kept as low as possible (see Fig. 3).

2.3 Brake System

APT has to stop from 155 mile/h within the existing signalling distances and allowance has been made for the failure of $12\frac{1}{2}\%$ of all brakes. Conventional brakes cannot accommodate the energy of stopping from such high speeds and a new 'hydrokinetic' brake has been developed. This brake blends with an on tread friction brake to give entirely adequate braking throughout the full speed range.

2.4 Testing

To assist the research programme tests were carried out by APT.E (a gas-turbine powered 4-car articulated train) 'POP' train (a locomotive hauled set) and numerous equipment and systems trials were based on coaching stock and locomotives. Subsequent reviews studied the future potential for the gas-turbine engine but the growing fuel crisis and commercial pressures for an electric APT terminated our interest in this field; future prime-mover APT's will probably be based upon the diesel engines used in HST.

The ability of an Advanced Passenger Train to significantly reduce journey time was dramatically demonstrated by APT.E when the 99 miles between London (St Pancras) to Leicester was covered in $58\frac{1}{2}$ minutes - an average of 101 mile/h compared with our present day best averages of 70 mile/h.

APT TILT SUSPENSION

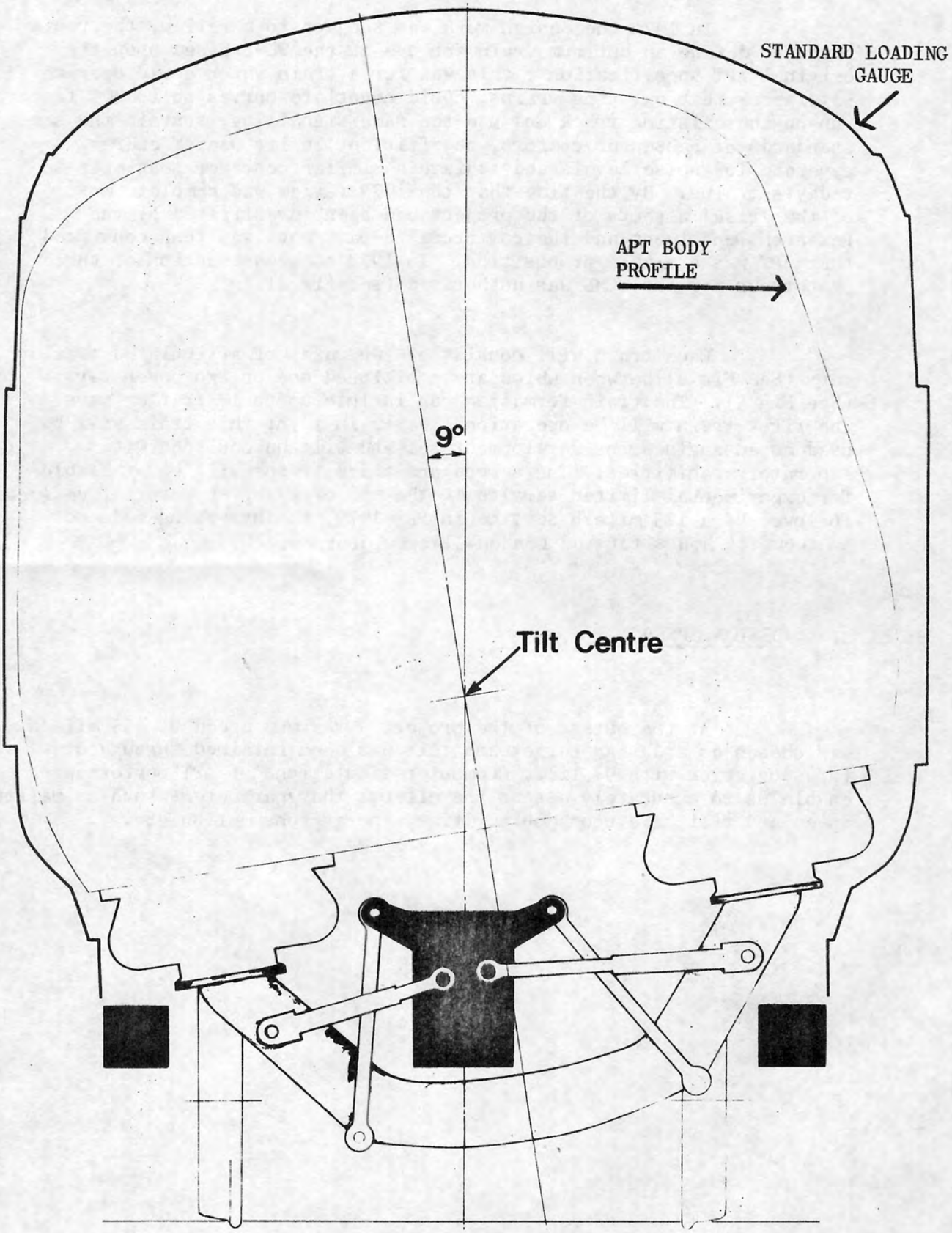


FIGURE 3

3. DEVELOPMENT OF APT-P

In 1973 the design work was subject to a review, the remit being to define an optimum train for use on the WCML based upon the original APT specification : this was for a train which could operate 50% faster than existing trains, could negotiate curves up to 40% faster, run on the existing track and use the same signalling, sustain the same standards of passenger comfort, be efficient in its use of energy, generate low noise levels and achieve a similar cost per seat mile to today's trains. By the time that the 1973 review was complete most of the 'risk' aspects of the project had been investigated by the Research Department and the commercial department was then convinced that APT was a viable proposition. In 1974 the construction of three prototypes for the WCML was authorised (see fig 4).

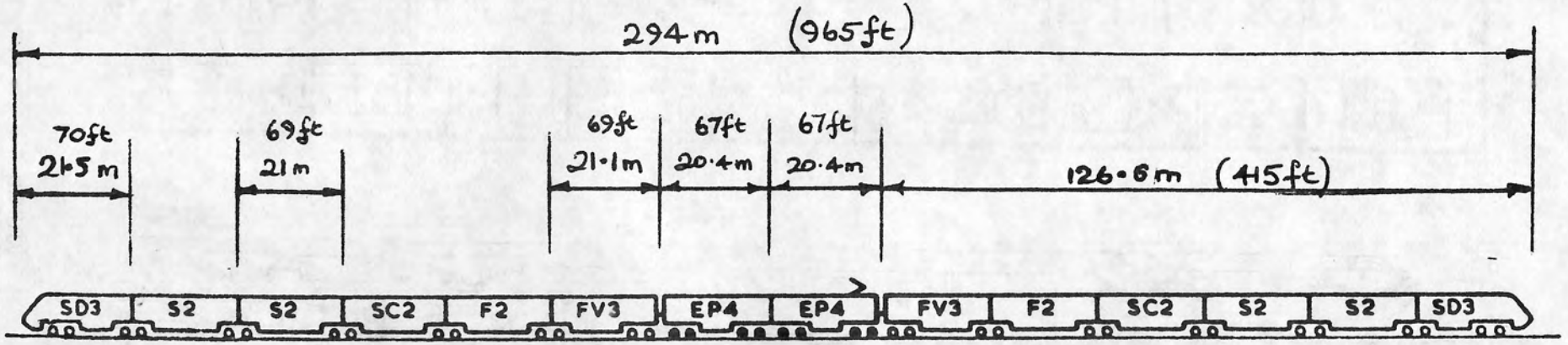
Each train will consist of two rakes of articulated trailer cars (See Fig 6) between which are positioned one or two power cars (See Fig 5). The train formation can include up to 12 trailer cars. The first train will be operational early in 1978; this train will be used as an engineering development set and will be equipped with laboratory facilities. The second and third trains will be available for experimental limited service at the end of 1978, at normal line speeds, followed by a 125 mile/h service in May 1979, timings being reduced to about $4\frac{1}{4}$ hours for the London-Glasgow journey.

4. DESIGN SPEED

At the outset of the project a maximum speed of 155 mile/h was chosen as a design target and this has been retained throughout - in association with 9° tilt. Computer simulations of APT performance enable us to accurately assess the effects that parameters such as maximum speed and tilt have upon journey time, energy consumption etc.

FIGURE 4 APT-P TRAIN FORMATION

Imperial dimensions to nearest foot.



OPERATOR'S CODES

DTS	TS	TS	TRB	TF	TBF	M	M	TBF	TF	TRB	TS	TS	DTS

SEATING CAPACITY

52S	72S	72S	28 S	47F	25F	-	-	25F	47F	28 S	72S	72S	52S

TOTAL SEATS 144 FIRST, 448 SECOND

APT.
1
7

GENERAL ARRANGEMENT OF POWER CAR.

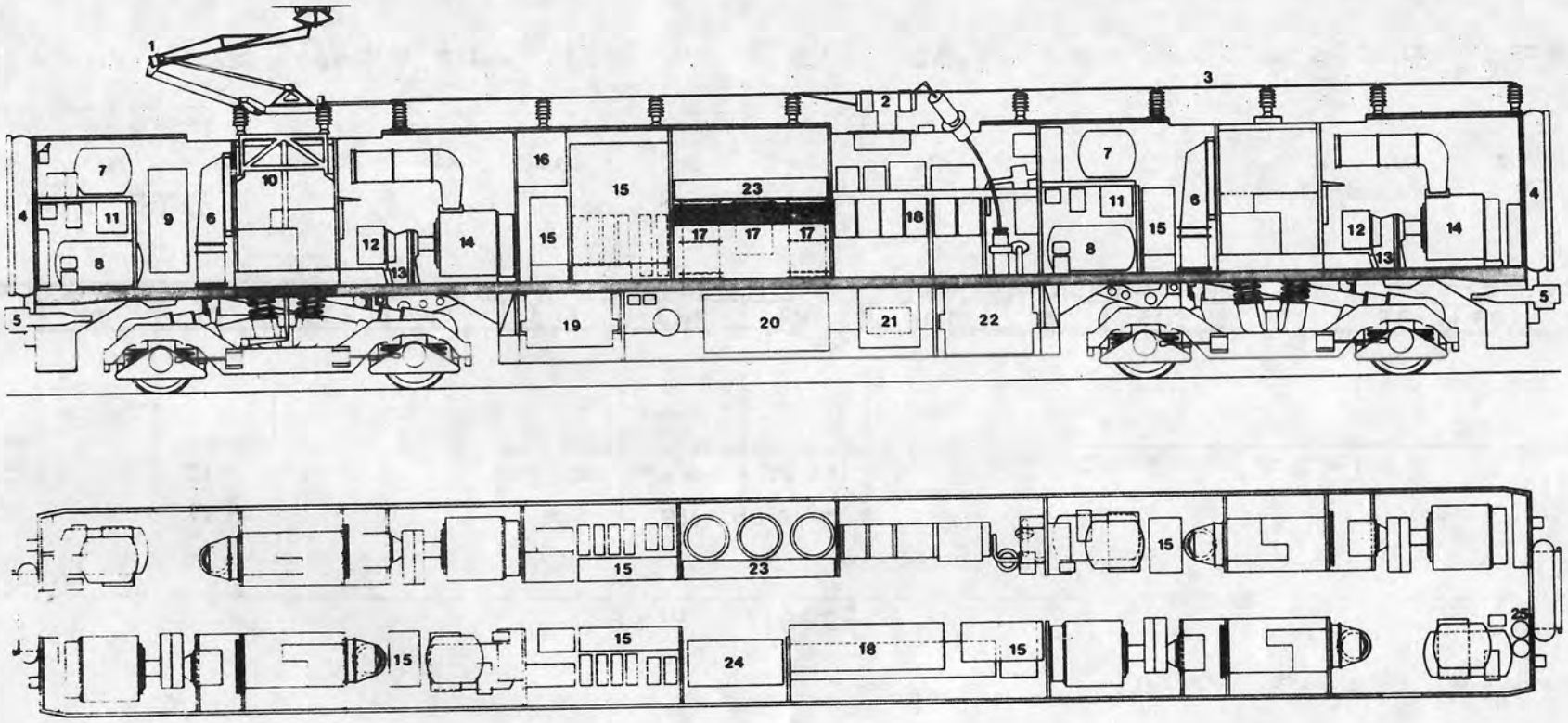


FIGURE 5

1 PANTOGRAPH.
2 CIRCUIT BREAKER.
3 H.T. BUS-BAR.
4 GANGWAY CONNECTION.
5 DRAWBAR.
6 HYDROKINETIC BRAKE RADIATOR & FAN.
7 HYDROKINETIC BRAKE AIR RESERVOIR.
8 HYDROKINETIC BRAKE WATER RESERVOIR.
9 DOOR.
10 PANTOGRAPH ANTI-TILT MECHANISM.
11 HYDROKINETIC BRAKE CONTROLS.
12 HYDROKINETIC BRAKE.
13 TRANSMISSION GEARBOX.
14 TRACTION MOTOR & BLOWER.
15 ELECTRIC CONTROL EQUIPMENT.
16 AIR COMPRESSOR
17 COOLING FAN FOR TRANSFORMER,CHOKE. THYRISTOR & TILT SYSTEMS.
18 THYRISTOR CONVERTORS.
19 CHOKE.
20 RADIATORS FOR TRANSFORMER,CHOKE, THYRISTORS & TILT SYSTEMS.
21 THYRISTOR COOLANT TANK & PUMP.
22 TRANSFORMER.
23 BATTERIES.
24 TILT SYSTEM CONTROL PACK.
25 FIRE EXTINGUISHER GAS BOTTLES.

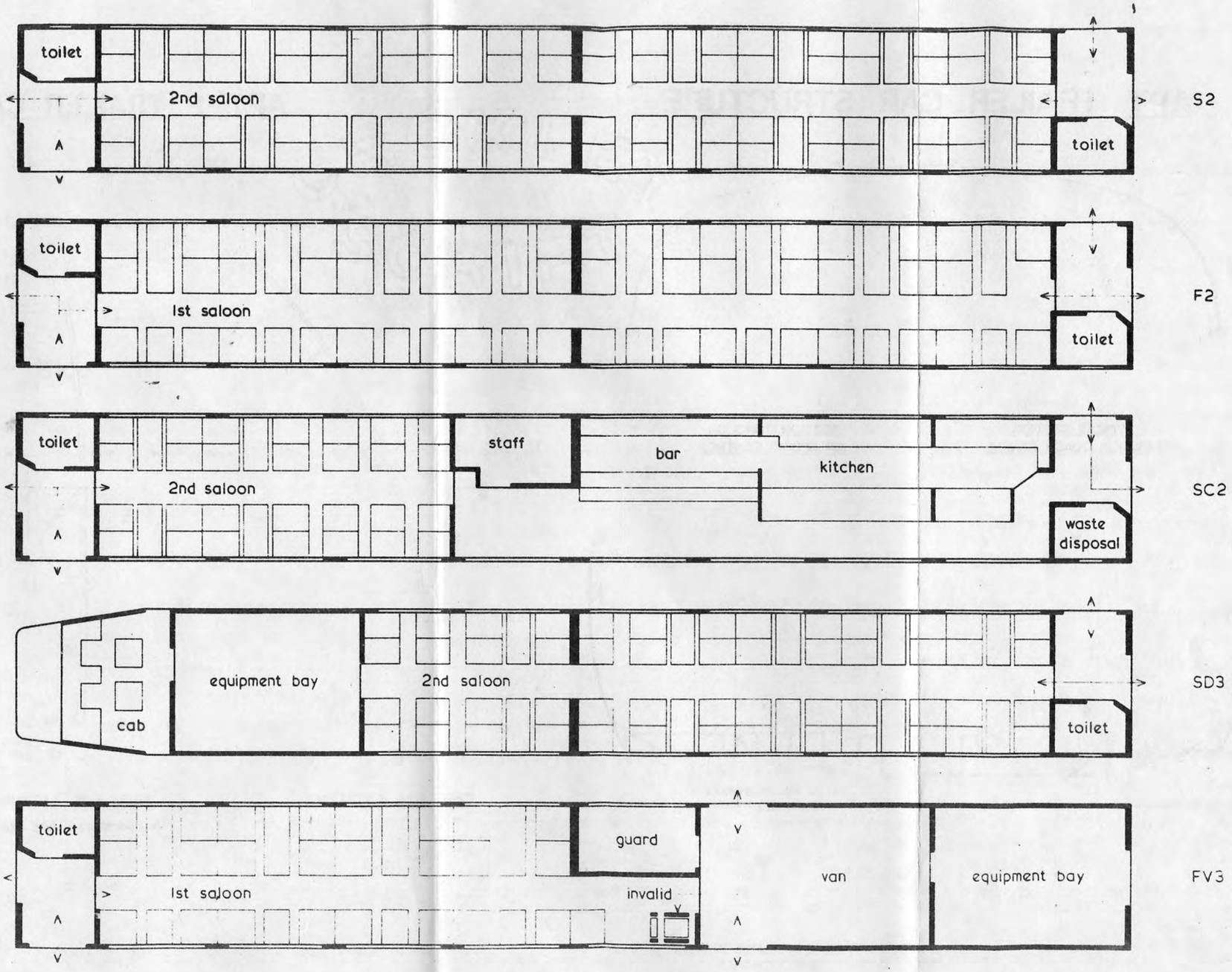
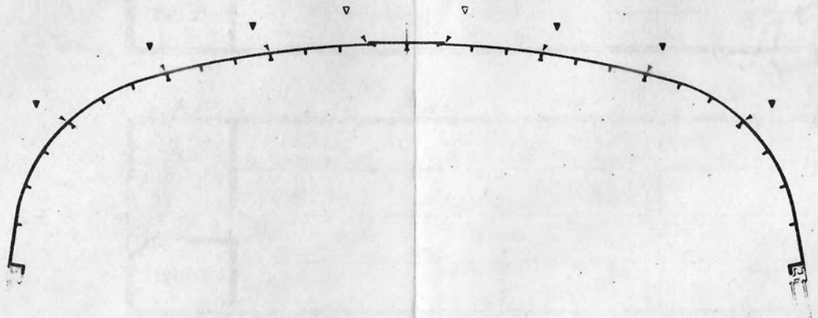


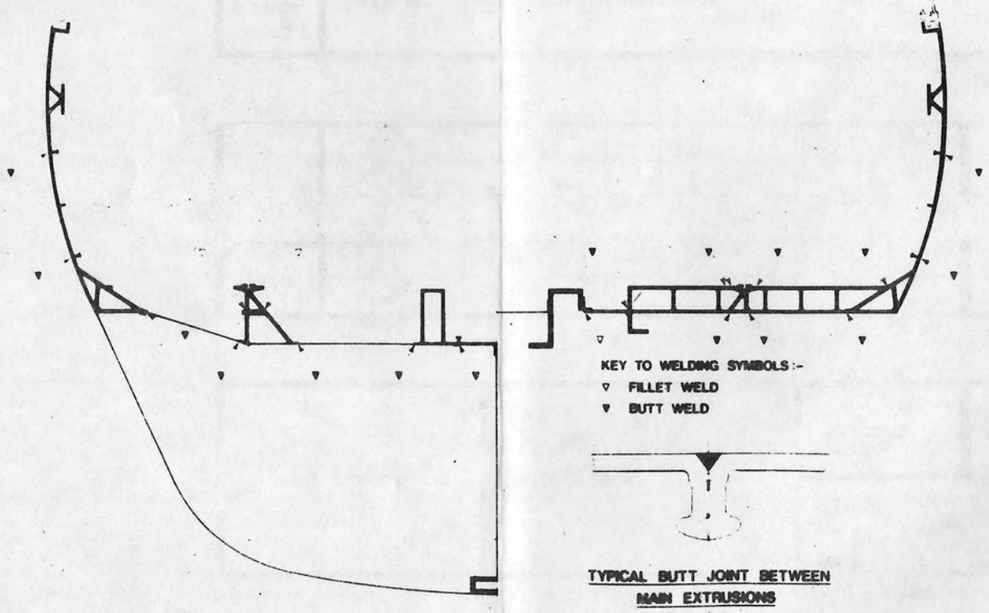
FIG. 6 – GENERAL LAYOUT OF APT-P PASSENGER VEHICLES

FIGURE 7

APT TRAILER CAR STRUCTURE



TYPICAL SECTION
THROUGH COACH CENTRE



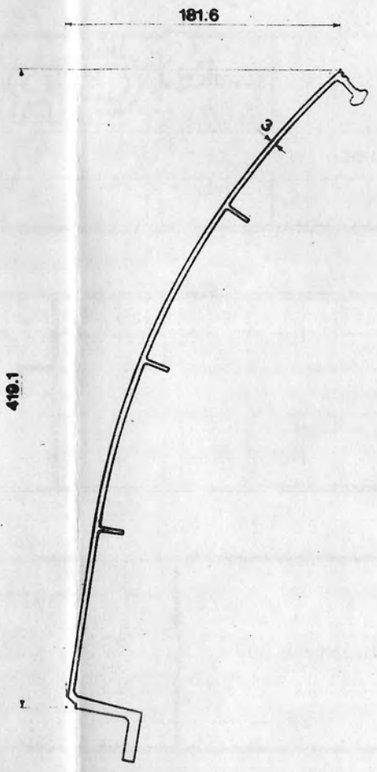
SECTION THROUGH
AIR SPRING CENTRES

KEY TO WELDING SYMBOLS :-
▽ FILLET WELD
▼ BUTT WELD

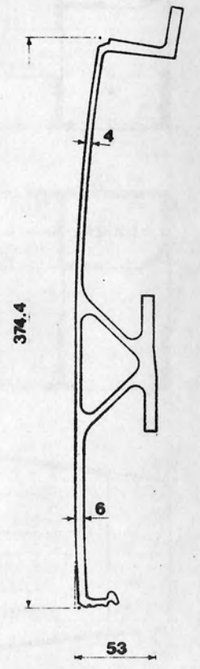
TYPICAL BUTT JOINT BETWEEN
MAIN EXTRUSIONS

FIGURE 8

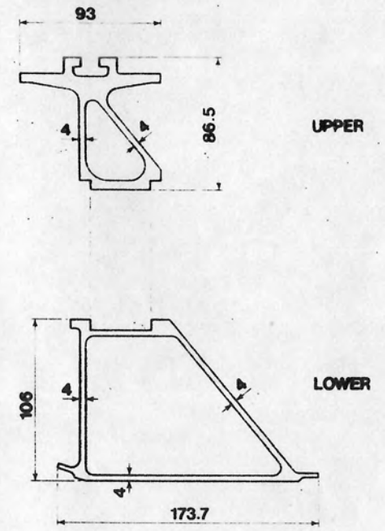
APT-P TRAILER CAR EXTRUSIONS



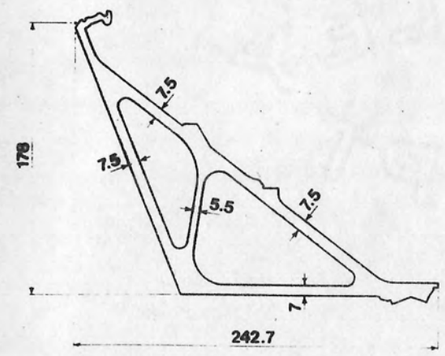
CANT RAIL EXTRUSION



WAIST RAIL EXTRUSION
(INCORPORATING SIDE SEAT RAIL)



SEAT RAIL EXTRUSIONS



SOLEBAR EXTRUSION

5. VEHICLE STRUCTURES

Lightweight vehicles are required not only for low total train mass but also for acceptable axle loads, especially on articulated axles. To meet the mass targets, APT trailer car bodyshells are constructed in aluminium alloy, giving a 40% weight saving over a conventional steel coach. Lightweight steel construction has been adopted for power car bodyshells.

All vehicle structures are designed to meet the UIC loading specification for main-line coaches, including the 2 MN (200 tons) proof buffing load. They are also designed to be stiff enough to avoid strong vibration coupling between body and bogie frequencies. The dominant design criterion tends to be stiffness rather than strength, as high flexural natural frequencies are essential for good ride quality at high speed.

5.1 Trailer Cars

The trailer cars of APT-E were designed as efficient semi-monocoque structures incorporating deep structurally-effective underbellies. When constructed, they confirmed that the strength, stiffness, and mass targets could be achieved using aluminium. The structural principles were proved to be sound, but the method of construction, using aircraft practices and close-pitch riveting, was not economic for quantity production. Thus, a method of construction was sought which offset the high material costs of aluminium for reduced labour costs. The target was to produce an aluminium shell for the same cost as a conventional shell.

The form of construction adopted for APT-P is based on extensive use of wide commercial-grade aluminium extrusions running the full length of the vehicle and making up the outer profile (see Figs 7 and 8 opposite). These are seam-welded together automatically. The completed bodyshell has a mass of 4.8 Mg (4.8 tonnes). As part of the development programme, a pre-prototype shell was built and tested to prove the production methods.

Although the main body structure is seam welded the requirement for adequate strength at the ends of the vehicles at floor level has necessitated the use of members made from different grades of aluminium alloy. The particular alloys used do not lend themselves to the production of welded joints of adequate strength, and bolted connections are therefore employed at these locations.

5.2 Power Cars

The power cars of APT-E were designed as simple steel space-frame structures with non-load-bearing skins so that modifications could be accommodated easily during the experimental programme. Indeed, at one stage the power cars were lengthened to improve dynamic stability.

The APT-P power car is a steel semi-monocoque structure with deep side skirts. High stiffness is attained with an efficient distribution of mass, resulting in a bodyshell mass of only 12 Mg. (12 Tonnes).